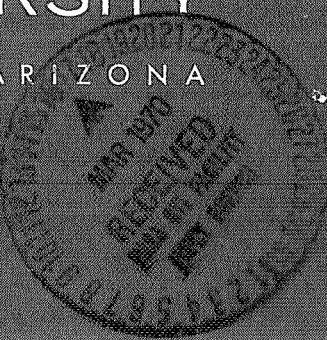


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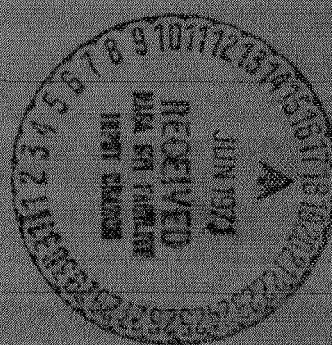
ANALYSES OF IRON METEORITES  
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**Analyses of Iron Meteorites**

**by**

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*Z*

Chemical analyses of iron meteorites, dating over a period of a century or more, have several times been gathered into compilations of great use to later investigators. These compilations including those by Farrington [1], Chirvinskii [2], Berwerth and Michel [3], Buddhue [4], and Yavnel and Dyakonova [5] have been either collections of all analyses published with no attempt to judge their reliability or averages of the chemical composition of the various meteorite types based upon more or less selected analyses. Farrington [1] has pointed out that

"Chemical analyses may be collected and grouped for purposes of record and comparison. For the first purpose it is desirable that all known analyses of the substances under consideration be collected; for the second, only those known to be complete and reliable are needed. A combination of these two purposes may perhaps be gained, however, by collecting all analyses and leaving to the judgement of the investigator the selection of those suited for the study of any particular phase of the subject."

In this paper an attempt is made to find some parameters upon which such a judgement may be made both with respect to using the analysis for comparison purposes and in deciding whether a new analysis should be made. Similar studies for the stony meteorites by Urey and Craig [6] and Mason [7] have proved to be quite useful.

The evaluation of the analyses of iron meteorites in several instances does not prove to be as easy as for chondrites in spite of their simpler composition. Generally speaking the iron meteorites are not as homogeneous as the chondrites and analysts are often faced with the presence of large troilite or schreibersite inclusions within cut faces. Usually these large inclusions are avoided, so in fact the analyses are not truly representative of the whole meteorite but only of the so-called metallic phase. This terminology is in itself not true because the specimens taken

may contain microscopic inclusions of troilite and almost always of schreibersite.

Ignoring the sampling problem, which as shown by Moss, Hey and Bothwell [8] is relatively minor except in the case of coarse octahedrites, the major problem is one of evaluating chemical accuracy.

The metallic phase of iron meteorites is made up primarily of the elements iron, nickel and cobalt alloyed in two mineral phases kamacite and taenite. Copper, which is present in concentrations of about 180 ppm in most iron meteorites, might also be considered one of the major ubiquitous elements. Other siderophilic minor and trace elements may be dissolved in the two metallic phases and sometimes distributed between these phases and other minerals found in the iron meteorites. Work by Goldberg et al. [9], Lovering et al. [10], and Wasson and co-workers [11] [12] has shown that some siderophilic elements like germanium, gallium and iridium rather than occurring with relatively uniform continuous abundances are found in groups sometimes ranging over two orders of magnitude. As more and better analytical data are accumulated, these groups are becoming better defined and are important in evaluating major as well as trace element abundances. There are, however, some iron meteorites which seem to be anomalous in many respects and defy generalization in evaluating their reported chemical composition.

In addition to the metallic phases of iron meteorites, other mineral inclusions are also commonly found. The most notable of these are sulfide nodules made up of the minerals troilite, daubreelite and other minor sulfides, graphite, the iron-nickel carbide, cohenite, and the iron-nickel phosphide, schreibersite. In addition to the macroscopic nodules of these

minerals, they also may be found as microscopic inclusions. This is particularly true of the mineral schreibersite. Chromium is often found as the mineral chromite,  $\text{FeCr}_2\text{O}_4$ . The metallic phase may contain smaller amounts of dissolved non-metallic elements common in these separate phases.

Weathering of iron meteorites is very common and the terrestrialization process may add selected trace elements to meteorites both on the ground and in laboratories and museums.

In sampling and analysing an iron meteorite those elements occurring predominantly in dispersed mineral phases may vary depending upon the amount of the dispersed phase taken in the sample. Most analysts taking a piece of iron meteorite consciously avoid large macroscopic inclusions and therefore most analyses tend to be of a metallic or inclusion excluding sample. It is safe to say that the reported analyses, including those in this paper, are best considered to be analyses of the individual sample rather than the whole meteorite. For inclusion rich meteorites a detailed statistical sampling combining chemical analysis with modal point counting would be necessary. For most iron meteorites we do not have enough total material or cut and polished surface area to accomplish this goal.

The elements in iron meteorites may be divided into three categories. First are the major constituents of the metallic phases iron, nickel, cobalt and copper; second, the elements found dissolved in the metallic phases and in non-metallic mineral inclusions such as carbon, phosphorous, chromium, sulfur and nitrogen; third are the variable and trace elements such as gallium, germanium, the noble metals and zinc.

It is the purpose of this paper to evaluate the reported analyses of elements in the first two groups commonly determined in routine analyses of

iron meteorites. As a basis for comparison, one-hundred iron meteorites were sampled by a newly adopted milling technique. Splits from the milled sample were then analysed for the elements nickel, cobalt, copper, phosphorous, carbon and sulfur. Nitrogen analyses were also done on the same samples but are not reported here because the containing mineral phase or location has not yet been identified.

#### Analytical Methods

Ten to twenty gram samples of iron meteorites were obtained by milling one to three millimeter size chips from cleaned and crust free cut surfaces of the individual specimens. The milling was done using a standard milling machine with a tungsten carbide cutting tool. Contamination from this tool appears to be minimal. It becomes dull not through attrition or chipping but rather through deformation causing rounding of the cutting edge. The chips were caught in an enclosing bag covering the milling head and sample.

A mechanical splitter was used to take suitable splits of the meteorite chips for wet and combustion analyses. For each of the analyses duplicate splits were taken from the same sample. The analytical results had a high degree of precision as shown by the analytical results in Table I.

For the wet chemical analysis approximately one gram samples were dissolved in aqua-regia and, when needed, hydrogen peroxide. The solution was evaporated to dryness and redissolved twice in hydrochloric acid. From this master solution nickel was determined by precipitation with dimethylglyoxime, cobalt was complexed with Nitroso R-salt and determined colorimetrically, and phosphorous was determined colorimetrically as phosphomolybdic acid. Copper values are from unpublished atomic absorption results by Nava and Moore. Carbon, sulfur and nitrogen were determined on

separate splits utilizing combustion techniques to open the samples. Carbon was determined by heating the sample in an oxidizing atmosphere in an induction furnace, converting any carbon monoxide formed to carbon dioxide and measuring the total carbon dioxide in a gas chromatograph. Sulfur was determined from a sample burned in an oxidizing atmosphere. The sulfur dioxide produced was determined by iodometric titration.

Iron was not determined although it would be very desirable to have a directly determined value for this major constituent. It is difficult to determine a constituent making up ninety percent of a sample with enough precision to match the other measurements. This would require a precision with four significant figures for the iron values to be useful in summing to one-hundred percent as an indicator of an undetected, unexpected component. Many of the analyses in the literature list iron values determined by difference but this is of limited value if minor elements present in the order of magnitude of one hundredth of a percent such as copper, carbon and germanium are not included in the analysis.

#### Data

The meteorites used in this investigation were selected at random from The Nininger Meteorite Collection at Arizona State University usually on the basis of their size and cut condition. Others were suggested as being of interest by Joseph Goldstein of the NASA Goddard Space Flight Center.

The two numbers reported in Table I for each element per meteorite represent analyses of two separate splits, not two aliquots from the same solution. In subsequent use of these numbers an average value was taken for each element. The values reported for nickel varied from 5.52 to 24.21 weight percent; those for cobalt from 0.32 to 1.03 weight percent; and phosphorous

from 0.01 to 1.13 weight percent. A cursory comparison of the cobalt values with those of older analyses indicates that the new ones in this investigation are in general lower than the earlier ones. This might indicate that the earlier analysts were not successful in their attempts to separate iron, nickel and cobalt from each other and precipitate each independently for gravimetric determination. Due to the chemical similarity of these elements this is a difficult job, at best, using hydroxide precipitation techniques. Earlier phosphorous determinations appear to be generally similar to modern ones. The median value determined in this study is 0.17 weight percent phosphorous.

Figure 1 is a plot of the cobalt vs nickel values determined in this investigation. Both a visual and statistical study indicate a positive correlation between cobalt and nickel. The best straight line through the values determined by a least squares fit has the formula:

$$\text{Co} = 0.0197 \text{ Ni} + 0.308$$

This line (A-A) is plotted on Figure 1. It is interesting to note that such a line does not pass through the zero-zero point on the graph. In view of the fact that the nickel concentration in iron meteorites rarely, if ever, falls below 5 weight percent, an extension of the line below this point has no statistical use. The coefficient of correlation computed for this straight line is 0.56. A value of 1.0 would indicate a perfect fit and one of 0 no fit. The value of 0.56 is well within the 95 percent confidence level for a sample of the size used in this study.

The standard error,  $S_{\text{Co-Ni}}$ , of estimate for the least square fit line in Figure 1 is calculated to be 0.091. On Figure 1 are drawn the limits

within which 68%, (B-B), 95% (C-C) and 99% (D-D) of the determinations should fall.

In making any selection of superior data it is necessary to make a decision on whether it is better to eliminate a correct result or accept an incorrect result. In this study the decision was made to use a ninety-nine percent confidence level and only reject as wrong analyses, or as very unusual meteorites, those that vary considerably from the correlations set up from this data.

The use of data from one technique in one laboratory has obvious advantages in setting up criteria as shown above. It is of interest to compare the above relationship with other modern investigations where the authors have analysed moderate numbers of specimens. Such studies have been published by Goldberg et al. [9] and Lovering et al. [10]. The data by Lovering et al. [10] may be divided into two groups. In the first where they determined both nickel and cobalt, their plotted value's all fall close to our line, well within the 95 percent confidence limit. For the remainder of their values they took literature values for nickel content and redetermined cobalt. For these meteorites only one out of twenty-eight meteorites fell outside of the 99 percent confidence limit. This is better than our own data where two analyses fell outside. It should be noted however that in all three of these cases the nickel values were high and the meteorites anomalous in other properties as well. For high nickel-iron meteorites it may require more detailed study of structure and trace elements to say with a high degree of confidence whether an analysis is bad or the meteorite unusual. In the data of Goldberg none of the thirty-one analyses done by them fell outside of the 99 percent confidence levels.

If all the meteorite analyses listed by Farrington in 1907 are considered, only 35 percent fall within the 99 percent confidence level. It is interesting to note that the analyses made by the analysts, J. Fahrenhorst, J. B. Mackintosh, L. Fletcher, O. Sjöström, and J. L. Smith are consistantly good.

There are other criteria which also may be used to eliminate some of the Farrington analyses which fall within the prescribed limits. Some of these analyses show nickel concentrations below five weight percent and should be eliminated, especially when they are listed as medium octahedrites as several are. Although it is not discussed within the context of this paper, a careful analysis of meteorite type, including modal analyses and band widths where appropriate, compared with the reported chemical analysis is a useful criteria for judging analytical quality. Also, on the basis of the trace element data available, it is becoming apparent that there are chemical trends among the major elements in the groups defined by trace element analysis. For example a comparison of phosphorous content of meteorites and the trace element groups defined by Wasson [12] shows that low phosphorous meteorites fall in groups IVa, IVb or IIIa and that within group IIIa there may be a positive correlation between nickel and phosphorous contents.

Because of their occurrence in variable phases, it is not possible to mechanically evaluate reported analyses for carbon, sulfur and phosphorous except that if they are present in large amounts their respective mineral phases should be observable in polished section

Criteria suggested for the evaluation thus include: First, that the nickel-cobalt values fall within the 99 percent confidence level shown in

Figure 1; second, that the nickel content be above 5 weight percent; and third, that acceptable iron values reported be direct determinations rather than determined by difference, unless a very complete analysis for phosphorous, carbon, sulfur, copper, germanium and possibly silicon has been undertaken.

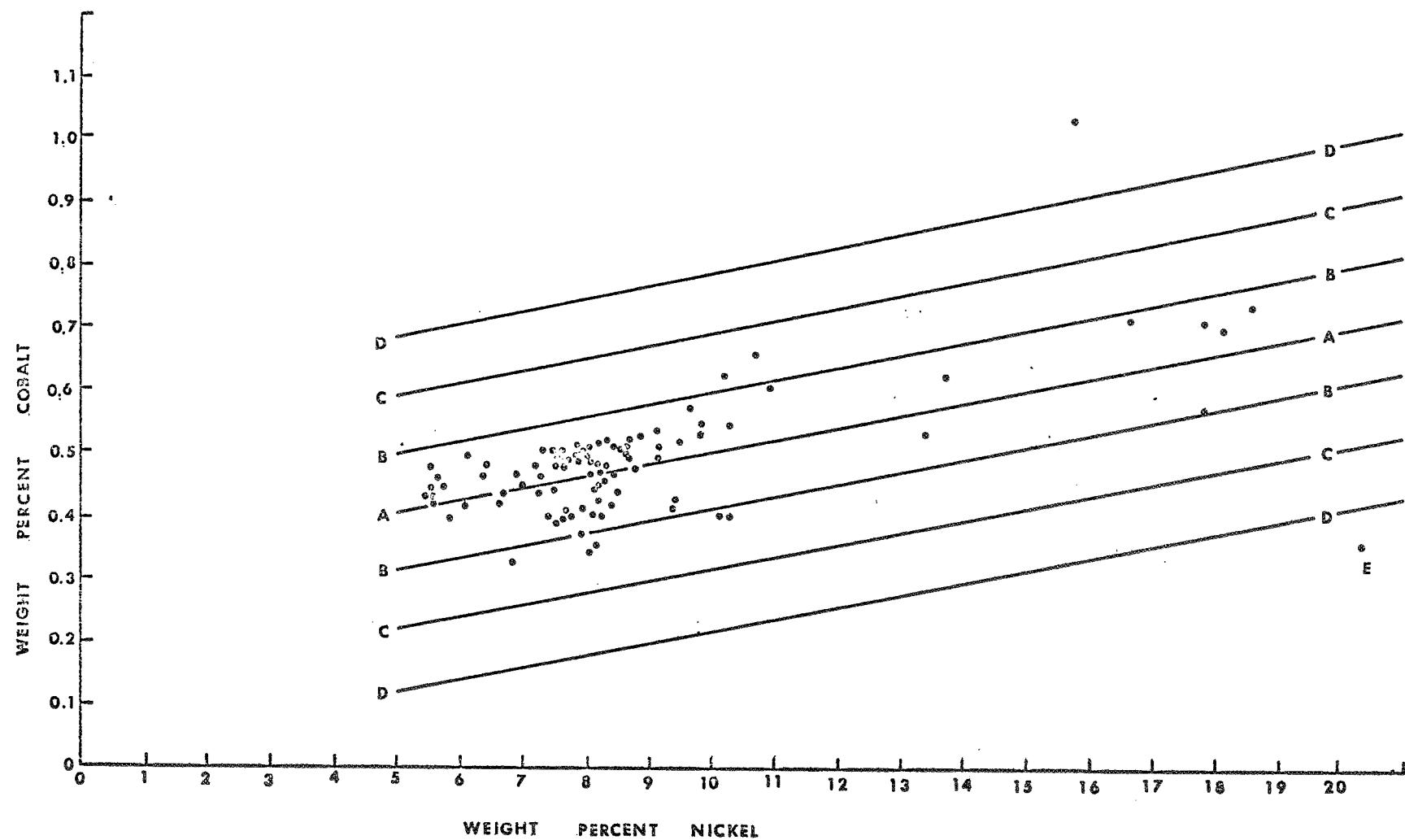
The least squares fit for the cobalt-nickel curve has some interesting implications. Cobalt appears to follow nickel rather than iron in its distribution. Since the straight line does not pass through the origin for the two elements, the ratio of nickel to cobalt is therefore not a constant. The ratio of nickel to cobalt would vary from 13.3 at 5.5 percent nickel to 22.2 at say 12 percent nickel. The ratio of nickel to cobalt in chondrites taken from Nichiporuk et al. [13] is about 21. This point on Figure 1 would be at a nickel content of 10.9 and a cobalt content of 0.52 which is higher than the great bulk of iron meteorites. This is the same nickel content selected by Lovering [14] to explain the observed abundances of the different types of iron meteorites derived by a differentiation process from a common parent melt. This or a similar model may give some satisfaction in explaining that the nickel-cobalt ratios in individual iron meteorites are not primary condensation ratios but rather secondary values imposed by a differentiation process. The best fit of a curve of primary values of nickel and cobalt would reasonably be expected to pass through the origin.

#### Acknowledgment

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**Figure 1.** Nickel vs cobalt in iron meteorites. Line A-A is best least squares fit straight line ( $Co = 0.0197 Ni + 0.308$ ) through points. Lines B-B, C-C, D-D are 68%, 95% and 99% confidence levels. Point E for the Tucson iron meteorite should be plotted at nickel 24.21, cobalt 0.43.

TABLE I Chemical Analyses of Iron Meteorites

Name	Number	Class	weight %					
			Ni	Co	P	C	S	Cu
Abancay	#209ax	Of	7.94	0.37	0.17	0.007	0.001	0.018
			7.94	0.36	0.18	0.008		0.018
Adargas (Concepcion)	#30ax	Om	9.98	0.56	0.48	0.057	0.008	
			9.96	0.54	0.46	0.020	0.009	
Ainsworth	#420.1	Ogg	5.62	0.48	0.18			
			5.52	0.49	0.19			
Pseudo - Apoala <sup>a</sup>	#475.1x	Of	8.16		0.18	0.040	0.022	0.015
			8.28		0.20	0.044		0.015
Arlington	#1a	Om	8.46	0.44	0.02			
			8.53	0.44	0.02			
Bacubirito	#17a	Off	9.86	0.77	0.16	0.033	0.006	0.015
			9.70	0.75	0.15	0.028	0.001	0.015
Bagdad		Om	8.36	0.46	0.11	0.007	0.004	
			8.28	0.44	0.12	0.006		
Bear Creek	#352.1x	Of	9.68	0.57	0.62	0.044	0.030	0.013
			9.62		0.64	0.042	0.030	0.013
Bear Lodge	#286ax	Om	7.89	0.51	0.14	0.005	0.002	
			7.87	0.50	0.13	0.005	0.002	
Bella Roca	#266a	Of	9.91	0.47	0.21	0.010	0.002	0.013
			9.98	0.47	0.20	0.011		0.013
Bendego	#355.1	Og	6.68	0.46	0.22	0.018	0.002	0.015
			6.60	0.47	0.21	0.013	0.002	0.015
Bennett County	#374.1	H	5.61	0.40	0.21	0.008	0.033	0.015
			5.57	0.43	0.25	0.008		0.015

TABLE I continued

-2-

Name	Number	Class	weight %					
			Ni	Co	P	C	S	Cu
Billings	#151a	Og	7.92	0.50	0.11	0.012	0.003	0.018
			7.90	0.47	0.09		0.002	0.017
Bodaibo	#773	Og	8.13	0.36	0.04	0.004	0.002	0.016
			8.07	0.32	0.03	0.004	0.002	0.015
Boguslavka	#749	H	6.11	0.42	0.14	0.013	0.575	0.017
			6.11	0.42	0.12	0.012	0.423	0.018
Bohumilitz	#767	Om	7.21	0.47	0.29	0.046	0.002	
			7.25	0.47	0.30		0.006	
Briggsdale	#535.1x	Om	8.26	0.52	0.18	0.008	0.003	
			8.23	0.50	0.17	0.008	0.003	
Bristol	#216.14	Of	8.12	0.40	0.05	0.008	0.001	0.013
			8.10	0.40	0.06	0.007	0.002	0.013
Burlington	#329.2	Om	8.55	0.49	0.22			
			8.49	0.48	0.24			
Butler	#137ax	Off	15.81	1.03	0.04			0.015
			15.79	1.02	0.05			0.015
Calico Rock	#706	H	5.75	0.44	0.27	0.013	0.006	0.014
			5.77	0.45	0.29	0.014	0.004	0.014
Cambrria	#359.1	Of	10.34	0.54	0.20	0.006		
			10.35	0.55	0.22	0.006	0.002	
Camp Verde (Canyon Diablo) <sup>b</sup>	#440.1	Og	7.27	0.43	0.18	0.005	0.002	0.013
			7.23	0.45	0.19	0.007	0.002	0.013

TABLE I continued

-3-

Name	Number	Class	Ni	Co	P	C	weight %	S	Cu
Campbellsville	#351.1	Om	8.56 8.58	0.51 0.52	0.27 0.29	0.015		0.007 0.008	
Canyon Diablo (1936)	#371.1	Om	8.19 8.18	0.44 0.43	0.34 0.34	0.026		0.009 0.007	0.028 0.028
Canyon Diablo (1949)	#586.1	Om	8.17 8.22	0.42 0.42	0.16 0.17	>.06		0.003 0.009	0.027 0.027
Cape York (Savik #1)	#403.1	Om	7.69 7.61	0.48 0.48	0.14 0.14	0.043 0.036		0.006 0.006	
Carbo	#494.1x	Om	10.30 10.27	0.63 0.60	0.26 0.26	0.022 0.021		0.018 0.013	0.032 0.032
Carlton	#35a	Of	13.44 13.42	0.54 0.51	0.15 0.12	0.049 0.047		0.004 0.003	0.025 0.025
Casas Grandes	#36a	Om	7.62 7.72	0.50 0.49	0.15 0.15	0.008 0.007		0.001 0.001	0.017 0.016
Casimiro de Abreu	#603.1	Om	8.53 8.45	0.51 0.51	0.24 0.22	0.009 0.009		0.001 0.002	
Charcas	#356.1x	Om	8.17 8.17	0.49 0.47	0.13 0.10	0.007 0.015		0.002 0.002	0.016 0.015
Charlotte	#382.1	Of	8.39 8.49	0.41 0.41	0.05 0.06	0.005 0.006		0.003 0.017	0.016 0.017
Chesterville	#251a	Da	5.84 5.87	0.39 0.39	0.24 0.25				0.015 0.015
Chile <sup>c</sup>	#388.1	Off	7.68 7.64	0.39 0.40	0.02 0.02	0.010 0.010		0.021 0.015	0.015 0.015

TABLE I continued  
-4-

Name	Number	Class	Ni	Co	P	weight %		
						C	S	Cu
Chinautla	#272a	Om	9.46	0.44	0.16	0.018	0.001	
			9.49	0.40	0.17	0.023		
Clark County	#181.9x	Om	6.82	0.33	0.18	0.015	0.056	
			6.93	0.32	0.19	0.015		
Cleveland	#242a	Om	8.93	0.53	0.42	0.013	0.008	
			8.87	0.52	0.38	0.013		
Coahuila	#32.10	H	5.63	0.43	0.20	0.010	0.009	0.015
			5.54	0.43	0.25	0.010		
Coahuila (Sanchez Estate)	#293a	H	5.56	0.44	0.26	0.010	0.002	0.015
			5.60	0.44	0.26	0.010		
Coopertown	#37b	Om	8.48	0.47	0.19	0.030	0.002	0.013
			8.46	0.46	0.18	0.027		
Costilla Peak	#190.1	Om	7.62	0.49	0.09	0.036	0.042	0.017
			7.50	0.48	0.09	0.037		
			7.54	0.49	0.07	0.047		
			7.56	0.49	0.07			
Coya Norte	#169.1x	H	5.65	0.40	0.29	0.004	0.032	0.014
			5.67	0.39	0.29	0.006		
Cruz del Aire	#794	Of	9.16	0.50	0.32	0.005	0.015	0.023
			9.14	0.48	0.30	0.004		
Dayton	#653.1	Dr	17.69	0.58	0.08	0.051	0.052	
			17.79	0.57	0.08			
Deep Springs	#357.1	Dr	13.68	0.62	0.01	0.011	0.010	0.007
			13.76	0.61	0.01	0.011		

TABLE I continued

-5-

Name	Number	Class	Ni	Co	P	weight %		
						C	S	Cu
Descubridora	#39a	Om	8.08	0.51	0.15	0.013	0.004	0.017
			8.06	0.52	0.14	0.011	0.006	0.017
Duchesne	#40a	Of	9.60	0.43	0.15	0.013	0.023	0.016
			9.55	0.40	0.15	0.006	0.022	0.016
Duel Hill (1854)	#257a	Of	10.16	0.40	0.15	0.016	0.009	0.020
			10.31	0.40	0.14	0.014		0.019
Franceville	#187a	Om	8.39	0.48	0.21	0.011	0.002	0.017
			8.39	0.47	0.21	0.009	0.005	0.017
Goose Lake	#438.2x	Om	8.23	0.49	0.26	0.063	0.003	0.017
			8.30	0.43	0.80	0.052	0.004	0.018
Grand Rapids	#54a	Of	9.12	0.53	0.20	0.026	0.007	0.030
			9.16	0.54	0.14	0.022	0.005	0.028
Hex River Mountains	#412.1	H	5.65	0.45	0.25	0.005	0.003	0.015
			5.72	0.46	0.25	0.008	0.002	0.015
Joe Wright Mountain	#484.1	Om	9.21	0.49	0.51	0.014	0.007	
			9.22	0.52	0.42	0.014	0.003	
Kayakent	#791	Om	8.12	0.46	0.27	0.012	0.004	0.015
			8.06	0.45	0.27	0.023		0.014
Kenton County	#66a	Om	7.54	0.48	0.08	0.005	0.063	0.017
			7.50	0.48	0.08	0.005		0.017
Kingston	#189a	Om	6.99	0.43	0.08	0.009	0.033	
			7.02	0.47	0.07	0.011	0.039	
Kyancutta	#285a	Om	8.08	0.47	0.18	0.012	0.008	0.017
			8.11	0.49	0.18	0.012	0.014	0.017

TABLE I continued

-6-

Name	Number	Class	Ni	Co	P	C	S	weight % Cu
La Grange	#291.3	Of	7.68	0.41	0.03	0.039	0.009	0.017
		Off	7.73	0.40	0.03	0.035	0.012	0.016
Lenarto	#70a	Om	8.74	0.52	0.26	0.009	0.003	
			8.65	0.53	0.25	0.009	0.003	
Livingston (Montana)	#526.1x	O	7.56	0.43	0.09		0.036	
			7.58	0.47	0.09			
Loreto	#600.2	Om	7.92	0.50	0.12	0.019	0.007	0.016
			7.85	0.48	0.11	0.016	0.010	0.016
Mart	#82a	Off	9.32	0.41	0.13	0.029	0.014	0.014
			9.26	0.41	0.13	0.030	0.016	0.013
Monahans	#256.1x	Dr	10.73		0.09	0.010	0.002	0.033
			10.75		0.08	0.008	0.003	0.032
Mount Sterling	#191a	Og	7.03	0.47	0.20	0.048	0.007	0.015
			7.05	0.42	0.20	0.047	0.003	0.014
Nejed	#86b	Of	7.80	0.39	0.03	0.005	0.001	
			7.75	0.39	0.03	0.005	0.002	
Norfork	#296.1x	Om	7.93	0.49	0.14		0.007	0.017
			7.97	0.50	0.13	0.002		0.017
Ogallala	#90.1x	Om	7.78	0.49	0.16	0.014	0.002	0.013
			7.78	0.49	0.16	0.016		0.013
Orange River	#322.1x	Om	8.63	0.49	0.25	0.010	0.005	0.013
			8.61	0.51	0.26	0.010	0.007	0.016
Osseo	#309.2x	Ogg	6.66	0.39	0.16	0.009	0.002	0.017
			6.70	0.45	0.16	0.009	0.003	0.016

TABLE I continued

-7-

Name	Number	Class	Ni	Co	P	C	weight %	S	Cu
Owens Valley	#145a	Og	8.70 8.64	0.49 0.52	0.17 0.24	0.009 0.008		0.004	
Para de Minas	#604.1	Om	8.22 8.15	0.35 0.35	0.06 0.06	0.003 0.003		0.002 0.011	0.014 0.014
Perryville	#172ax	Off	9.87 9.75	0.54 0.52	0.31 0.30	0.018 0.020		0.002 0.003	0.027 0.027
Plymouth	#160a	Om	8.68 8.70	0.50 0.49	0.26 0.23	0.015 0.016		0.004 0.005	
Ponca Creek	#421.1	Ogg	6.70 6.72	0.47 0.43	0.74 1.13	0.011 0.016		0.030 0.011	0.011 0.011
Putnam County	#246.2	Of	8.10 8.14	0.35 0.33	0.04 0.04	0.016 0.012		0.015 0.008	0.016 0.016
Red River	#252a	Om	7.82 7.89	0.48 0.50	0.12 0.12	0.045 0.017		0.004 0.004	
Reed City	#154a	Og	7.63 7.61	0.50 0.50	0.27 0.22	0.013 0.014		0.019 0.024	0.014 0.014
Rifle	#528.3	Og	7.29 7.31	0.46 0.47	0.15 0.16	0.170 0.185		0.003 0.002	0.014 0.014
Rodeo	#101ax	Of	10.54 10.60	0.65 0.66	0.71 0.79	0.046		0.010 0.016	0.026 0.026
Sacramento Mountains	#372.1	Om	8.04 7.98	0.40 0.42	0.11 0.09	0.005 0.004		0.002 0.005	
San Angelo	#159.2	Om	7.57 7.67	0.46 0.49	0.10 0.10	0.012 0.016		0.060 0.057	0.018 0.018

TABLE I continued

-8-

Name	Number	Class	Ni	Co	P	C	weight %	S	Cu
Santa Apolonia (Nativitas)	#112a	Om	7.39 7.39	0.50 0.50	0.10 0.10	0.021 0.027	0.007 0.011		
Santiago Papasquiaro	#721.4	O	7.51 7.51	0.45 0.45		0.003 0.003	0.022 0.021		
Scottsville	#164a	H	5.48 5.52	0.44 0.43	0.23 0.19	0.008 0.007	0.005 0.009	0.015 0.016	
Silver Bell	#793	Ogg	6.44 6.42	0.50 0.45	0.24 0.24	0.022	0.004 0.003	0.011 0.011	
South Byron	#358.1x	Dr	17.77 18.57	0.71 0.80	0.21 0.23	0.007 0.005	0.011 0.008	0.036 0.036	
Spearman	#230.3	Om	8.35 8.51	0.52 0.51	0.36 0.35	0.013 0.012	0.007 0.001	0.013 0.013	
Staunton	#155a	Om	8.79 8.81	0.47 0.48	0.23 0.25	0.046	0.025 0.029	0.014 0.014	
Thunda	#121a	Om	8.17 8.07	0.45 0.48	0.25 0.25	0.024 0.023	0.011 0.070	0.016 0.017	
Tlacotepec	#113.2	Dr	16.56 16.56	0.69 0.73	0.04 0.05	0.004 0.005	0.004 0.001	0.001 0.001	
Toluca	#128.42	Om	8.08 7.96	0.49 0.49	0.15 0.16	0.024	0.002 0.002	0.016 0.016	
Tonganoxie	#120a	Om	7.84 7.79	0.50 0.49	0.12 0.13	0.009 0.008	0.022 0.023	0.017 0.017	
Tucson (Carleton Iron) <sup>d</sup>	#122a	Dr	24.21	0.43	0.06			0.014 0.013	

TABLE I continued

-9-

Name	Number	Class	Ni	Co	P	C	weight %	S	Cu
Weaver Mountains	#313.2	Dr	18.16 18.06	0.70 0.70	0.10 0.10	0.004 0.003		0.010	0.001 0.001
Williamstown	#161a	Om	7.54 7.59	0.48 0.49	0.07 0.08	0.009 0.012		0.036	
Wood's Mountain	#393.1x	Off	8.25 8.19	0.39 0.41	0.05 0.05	0.045 0.040		0.010	0.017 0.017
Yanhuitlan	#129a	Of	7.45 7.51	0.39 0.40	0.02 0.02	0.038 0.036		0.032	
Yanhuitlan (Misteca) <sup>e</sup>	#162a	Of	7.60 7.58	0.39 0.39	0.02 0.02	0.011 0.010		0.056	
Youndegin	#157a	Og	6.96 6.93	0.47 0.45	0.21 0.21	0.005 0.005		0.030	0.015 0.015
Zacatecas (Witchita Co.) <sup>f</sup>	#232.1	Og	6.11 6.19	0.49 0.49	0.63 0.59	0.015 0.042		0.186 0.290	

<sup>a</sup> Specimen listed as Apoala in The Nininger Collection of Meteorites but different from 2 kg mass in Chicago.

<sup>b</sup> Camp Verde probably a moved piece of Canyon Diablo.

<sup>c</sup> This meteorite listed under Dehesa in Prior-Hey catalog. This classification is doubtful and meteorite should be considered as from unknown Chilean locality.

<sup>d</sup> This analysis of Tucson greatly differs from those reported in Prior-Hey catalog. This specimen reported to have been obtained by Nininger from California Division of Mines Collection which listed it as the Carleton Iron.

TABLE I continued

-10-

<sup>e</sup>Misteca as listed in The Nininger Collection of Meteorites is considered to be Yanhuitlan by J. Wasson and V. F. Buchwald.

<sup>f</sup>Witchita Co. as reported in The Nininger Collection of Meteorites is considered to be Zacatecas by V. F. Buchwald.